Investigation of a broken pile-shoe from a Roman bridge

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ABSTRACT: A Roman pile-shoe made from four iron bars had breaks in three bars. One break was a recent impact fracture. A sample containing one of the fracture surfaces was broken into large fragments with a hammer. These were investigated fractographically, metallographically, and by surface and bulk chemical analyses. The fractures were brittle and primarily intergranular. The metal was a coarse-grained phosphoric wrought iron (0.52wt% P) with very low silicon, manganese and sulphur contents, and extremely low carbon content (0.0033wt% C). This extremely low carbon content and coarse grain size indicate decarburisation during smithing. Furthermore, the combination of extremely low carbon and high phosphorus contents is concluded to be the most probable reason for the impact brittleness. This could have been facilitated by a notch effect due to surface corrosion. The significance of the embrittlement and surface corrosion is considered with respect to conservation of archaeological iron objects, including similar pile-shoes.

Introduction

Obstacles in the Maas riverbed, near the town of Cuijk in the Netherlands, were recognised in the early 1990s to be the remains of a Roman bridge. An archaeological recovery programme was set up (Goudswaard 1996; Goudswaard et al 2000), with the primary assistance of divers from the amateur archaeological organisation Mergor in Mosam (MiM). The recovery programme resulted in finding many stone blocks and more than 100 oak piles. The remains of the piles were 2–3m long, 0.3–0.4m square above the pointed lower ends, and some were still covered at these ends by iron pile-shoes. The piles (and hence the pile-shoes) have been dated to the 4th century AD. Dendrochronological investigations of the wooden piles showed that the bridge was built in three stages between 340AD and 400AD (Haalebos et al 2002).

Each pile-shoe was made from four iron bars, joined by heating and hammer-welding to form a point. The bars had approximate dimensions of 13x40x500mm. One pile-shoe was observed to have three broken bars, and at least one break was recent. This was an impact fracture owing to the pile-shoe falling onto the floor of a storage area. MiM sent the pile-shoe to the museum, Het Valkhof, for initial examination. Figure 1 shows the breaks and a sawn-off slice containing the upper fracture surface of the recent break; Figure 2 shows the lower fracture surface. Over the centuries the bar had corroded to varying depths, up to about 0.5mm. The largely internal fracture had shiny facets, some of which were up to 3mm in size. This unusual and obviously brittle fracture prompted a detailed investigation.

Experimental scope of the investigation

The sawn-off slice (Fig 1) was struck on a side surface by a hammer, resulting in brittle fracture into large fragments. These fragments were then used for the investigations summarised in Table 1. This ‘sampling’, though highly unorthodox, was effective and confirmed the ambient temperature impact brittleness of the bar.

As the results accumulated, it became clear that fresh fracture surfaces should be examined, if possible, for evidence of elemental (phosphorus) segregation to grain boundaries. Unfortunately, specimens could not be made for in vacuo fracture and examination by Auger electron spectroscopy (AES). The alternative was to break a